were in the summer or autumn series, and the isotherms of both air and sea run much closer together. On November 25 there is a difference of 30° in the sea temperature in the distance of 340 miles to the south-east of Newfoundland, whilst on the eastern side of the Atlantic the same difference of temperature, 40° to 70°, spreads over 2360 miles. This disparity between the difference of temperature on the western and eastern sides of the Atlantic is quite common throughout the whole period of the charts, but not always to so large an extent. The charts of December 15 and 19 are other instances which show this difference, and on January 6 there is a difference of 30° (from 30° to 60° F.) in 120 miles off the south of Newfoundland, whilst on the eastern side there is only an equal difference of temperature (50° to 80°) in 3300 miles. The largest differences of temperature occur between latitude 40° and 45° N., and longitude 40° to 60° W., which is the area most affected by the meeting of the warm water of the Gulf Stream and the cold Polar current, and the weather which is given on each chart shows that there is almost constant rain in this position, and it is also the breeding-place of many a storm area, and storms when generated have a decided tendency to keep in the track of the Gulf Stream.

These synchronous charts will materially aid investigators in tracing the connexion between the weather in the British Islands and that over the Atlantic, and as it is not possible at present to know what is going on immediately to the westward of us, it is the more necessary to deduce, if possible, laws which regulate the changes from time to time. By the publication of these charts the Meteorological Council afford opportunity for testing many theories. Among these may be mentioned the theory of indraft of wind towards the centre of a cyclone, if this is not already pretty conclusively proved Light is also thrown upon the question as to the position of rain with regard to the position and development of the general storm area, and upon many other inquiries of a similar nature. We hope that after the two remaining parts of the work have been completed the Council will see their way to undertake a thorough discussion of the material which the charts contain.

A REVIEW OF LIGHTHOUSE WORK AND ECONOMY IN THE UNITED KINGDOM DURING THE PAST FIFTY YEARS.[1]

II.

THE fifty years of the present reign have been distinguished with regard to lighthouse illumination by the development in this country of the beautiful dioptric system of Augustin Fresnel. In 1837, this system had been established in France fifteen years, but had only just been introduced into Britain, where the catoptric system was in full operation. Parabolic reflectors formed of facets of silvered glass were used in the Mersey lighthouses so far back as 1763, and at Kinnaird Head, in Scotland, in 1787. In 1804, perfected reflectors of silver plate rolled upon copper were used at Inchkeith, and similar reflectors have been ever since employed. To Teulère must be attributed the honour of the invention of these parabolic mirrors, in 1783. The Inchkeith Lighthouse is also notable as the first in Britain to receive a Fresnel apparatus (1835), through the exertions of Alan Stevenson, who placed the next one at the Isle of May (1836), and the third at the Start (1836). These lights were all of the first order, Start and Inchkeith being revolving, and Isle of May fixed. They were constructed by Messrs. Cookson, of Newcastle, who subsequently constructed at least a dozen others, mainly as regards the refracting portion.

The lenticular system, as received from Augustin Fresnel by Alan and Robert Stevenson, comprised four principal optical agents of glass, viz. the cylindrical refractor, the totally-reflecting prism, the refracting vertical prism, and the annular lens. These have been continued in use, with few modifications, until the present day, while his auxiliary elements, such as the small inclined lenses, the silvered metallic zones, and the plane silvered glass mirrors, have been abandoned. The first-order fixed light of Fresnel came well-nigh complete from his hands, and has remained unchanged in size and character, save as relates to the number of prisms above and below the lenses, which has been increased from 19 in all to 26, and as to the joints of the lenses, which have been made inclined instead of vertical, the latter improvement being due to Alan Stevenson, who also introduced a refractor of more truly cylindric form. It is in the apparatus of revolving sections that the most striking ameliorations have been effected. The French engineers added little between 1822 and 1852 to Fresnel's original work, a few combinations or modifications of his elements to produce flashes alternately with fixed light being nearly all. But between 1849 and 1852 the great improvement known as the holophotal system was elaborated by Mr. Thomas Stevenson. It is difficult to describe without drawings the various applications to both catadioptric and dioptric instruments of this principle, by which the light of maximum intensity, or the best utilization of all the rays, was attained. The first *catadioptric* holophote was employed at the North Harbour, Peterhead, in 1849. Better forms were realized in 1864. The first use of holophotal metallic mirrors above and below the annular lenses of a large revolving light was at Little Ross. These mirrors, which needed no small auxiliary Fresnel lenses, were, instead of being plane, like Fresnel mirrors, generated by a parabolic profile passing round a horizontal axis. The typical *dioptric* holophote is a central refracting lens of usually three elements, with a series of concentric holophotal totally-reflecting rings, forming an instrument of varying diameter and focal distance, condensing into a parallel beam all the front arc of the diverging sphere of rays. The holophote is perfected by a glass spherical mirror of totally-reflecting prisms so shaped and set as to return all the back hemisphere of incident rays through the flame, to be parallelized and sent out with the front hemisphere of rays. This spherical mirror in its most effective form was the invention, in 1861, of Mr. James Chance, who generated the double-reflecting prisms or zones round a vertical instead of a horizontal axis, separated them, and divided them into segments or panels, thus making it practicable to increase the radius of the mirror and apply it to the largest apparatus as a most useful adjunct. In this instrument the image of the flame is not reversed, and the light sent back is at least three-fourths of that received.

But the most important application of the holophotal system was to the dioptric revolving sea-light. The totally-reflecting zones above and below the refracting lenses were generated round a horizontal instead of a vertical axis, and made to work in complete unison with the lenses, the light being parallelized in every plane from top to bottom. The first holophotal sea-light was the North Ronaldshay, in 1851. Since that date every revolving light with prisms has been holophotal. It has been estimated that the modern plan gives light five or six times more intense than the original plan.

Another material addition to the resources of the lighthouse engineer has been contributed by Mr. Thomas Stevenson in the azimuthal condensing system. This is, briefly, an arrangement of the optical agents before described, and of some others specially devised, by which either one arc of the horizon is illuminated by a beam of the greatest attainable intensity while the rest is dark, or else two or more sectors are lighted with equal or with unequal intensity while the others are dark; these distinctions being governed by the nautical requirements as to range and direction of the sea-coast, channel, or harbour where the light is established. The beams thus sent out may be white or coloured, the differences in coloured media themselves, or, as compared with white light, being equalized approximately by the instruments used. The condensing method has been applied more freely to the smaller than to the larger orders of apparatus during the past twenty-five years; and among the most beautiful illustrations of the system, designed not alone by Mr. Stevenson, but by Mr. Chance, Mr. Alan Brebner, and Dr. Hopkinson, may be cited the Buddonness, the Isle Oronsay, the Lochindaal, the Dartmouth, the Hoylake, and many apparatus for certain narrow seas in Australia. But the large lights of Orme's Head, Dungeness, Bidston, Longships, St. Tudwal's, Dublin Bay, and McArthur's Head, may also be selected as good examples of the condensing plan.

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[1] Continued from p. 105.

A third and very valuable improvement is the group-flashing system of Dr. John Hopkinson, F.R.S., by which a new series of characteristics has been added to revolving lights. This invention dates from 1874, and consists in so shaping and combining on unequal axes the panels of an apparatus that a double, triple, or fourfold flash may be produced, each flash of the group being of such duration and divided from another flash by such an interval of time that compass-bearings may easily be taken from the ship; while each group is separated from another group by a longer interval, the whole period being one of the usual periods of revolving lights, such as half a minute. Thus, while adequate power is maintained for each flash, an unmistakable distinction is established. This plan became rapidly popular. The Trinity House were the first to apply it, in 1875, to the catoptric floating light on the Royal Sovereign Shoals, near Hastings. The next applications were to a dioptric light for Mexico, and to the Little Basses light, Ceylon. It is now used all over the world. At the Casquets, in 1876, it enabled the Trinity Corporation to dispense with two of the three lights hitherto employed, and show from one tower a half-minute light in triple flashes, each lasting two seconds, each interval between them three seconds, and the long interval between the groups eighteen seconds. The great lights of Bull Point, Hartland Point, and Eddystone are other examples of double and triple group-flashing by optical combinations.

The use of colour in lighthouse practice has been gradually diminishing since 1837, and is now almost restricted to harbour-lights and ship-lights, with a few cases of fixed sea-lights where a danger is to be marked over a narrow sector. The loss by absorption in red and green, the only two colours available, being from 60 to 80 per cent.—a loss slightly redeemed in the case of red by a certain relative superiority to white in thick weather —it is obvious that colour must sooner or later disappear from the list of effective lighthouse agents. Meanwhile the power of a coloured beam (without regard to the illuminant) has been optically enhanced by one of two methods, superficial amplitude and azimuthal condensation.

Where a revolving light is to show, in alternate or other series, red and white beams, the power may be approximately equalized by assigning to the red a certain greater angular breadth in the panels of prisms and lenses than to the white. The Wolf Rock light (1869), the Flamborough Head (1872), the Hartland Point (1874), were so treated by Mr. James Chance, though with different arrangements of panels, the average proportion being 73 for the red, and 27 for the white. The coloured glass plates used were of a selected tint of "copper ruby." The second method, condensation, is mainly applicable, as before mentioned, by means of vertical prisms and other agents to lighting sectors of the horizon, or to securing perfect definition between two coloured arcs or between a white and a coloured arc. The Kingswear fourth-order light, Dartmouth (1865), designed by Mr. Chance, is an excellent example. In a seaward arc of 45° there is a central white beam of 9½° between a red beam of 17¾° and a green beam of 17¾°. Ten vertical prisms were used, four condensing the lights on the border of the red and white, and four on the border of the green and white, while two augmented the central beam. The fairway channel to the harbour is indicated by the coloured light, and the bright beam constitutes a sea-light which is frequently observed at a distance of sixteen miles, though the lamp is inferior to the lamps of to-day.

The signal-lights of the port and starboard sides of a vessel are coloured in order that a marked contrast may be visible at a distance of at least two miles, and her course and evolutions plainly understood. But the great inferiority of green to red, and of both to white (the third signal carried by a steamer being a white light), combined with the imperfection of the optical apparatus and of the burner used, renders too many ship-lights lamentably untrustworthy at even this short range, and can only tend to multiply such terrible collisions as those with which we have become familiar during the past fifteen years. It might be impracticable, on account of weight or cost, to introduce condensing agents into side-lights generally, though Mr. Thomas Stevenson, ever foremost in the van of improvement, tried them on the small steamer *Pharos* in 1866; but there can be no sufficient reason for not adopting such lenses of true lighthouse types as are now made for the purpose in Birmingham and Paris, and in not fitting them with the incandescent electric light in two different degrees of power, so as to equalize nearly the red and green lights, and in not making them both equal in visibility to the white; thus securing an effective signal for the adequate protection of life and property at sea. The writer has long, but with small success, advocated this course. Public opinion, however, may yet be stimulated by some crowning disaster to insist on a reform so urgently needed, and so perfectly easy to realize.

In 1873 the first dioptric light established in England, Start Point, received its present apparatus in substitution for the old Fresnel lenses and concave mirrors. The new revolving light, the design of Mr. Chance, and which was repeated in 1874 at Cape Bon, Africa, and the South Stack Rock, Holyhead, was composed symmetrically of six sides of 60°, with the usual upper and lower prisms, the central lens having nine elements in circular settings. The panels are thus the widest in azimuth hitherto constructed, except some of those of Flamborough Head, which subtended 69½°, or the four holophotal quadrants constituting the South Stack Low Light (1879), designed by Dr. Hopkinson, and the only existing light of the kind. By a subsidiary arrangement of totally-reflecting prisms and a holophote, a fixed red beam at Start Point was projected to a lower chamber in the tower, and thence sent out to mark the position of certain rocks. The Watling Island (Bahamas) second-order double-flashing light of 1885, designed by Dr. Hopkinson, is a unique specimen of holophotal circular settings, with the most recent improvements.

A remarkable variation of the usual elements of a dioptric sea-light dates from 1879 or 1880. Lower prisms for sea-lights had, at the suggestion of the writer in 1874, been suppressed on several occasions; and for port-lights, Messrs. Chance had dispensed with all prisms, and raised the lenses to a vertical angle of 80°. But now it was determined to produce a first-order apparatus with refractors only, extending the vertical angle to 92° from 56° or 57°, the old normal height. This was attained by Messrs. Chance by means of dense flint glass in the superior and inferior limits. The power of the lenses, always counting for 75 per cent. of that of the complete light, was thus considerably augmented, while the cost and bulk were reduced, though doubtless at the expense of symmetry. The first-order lights, Anvil Point (Dorset), the Eddystone, and the Minicoy (Indian Sea), were constructed on this principle at Birmingham (1880-83). In the case of the Eddystone, two apparatus exactly alike were employed by the Trinity House—one superposed on the other, and each lighted by its own lamp, the whole height of optical glass exceeding 12 feet. The plan of superposed lenses was first suggested, in 1859, by Mr. J. W. D. Brown, of Lewisham, and first practically set forth, in 1872, by Mr. John R. Wigham, an engineer of conspicuous ability, in connexion with his large gas flames for Irish lighthouses; and it has been since fully approved and adopted by the Trinity House. The great lights of Galley Head, Howth Bailey, and Rockabill attest the excellence of this arrangement of lenses, and the Eddystone biform (1881) is not less successful.

The enhancement of illuminating power through the amplification, vertical and horizontal, of lenticular panels has been described. But a more emphatic change, associated with the name of Stevenson, has recently been consummated. The radius or focal distance of Fresnel's first-order light is 920 millimetres. The Fresnel of our time proposed a radius of 1330, and such a lens has been already constructed in France. The name "hyper-radiant," given to it by Mr. Stevenson, seems hardly so accurately formed as "hyper-radial," which was independently suggested by the writer in 1885, although the new lens will be excellently adapted to the large flames of the day, at once utilizing their volume and not suffering from their heat. In the lights for the Bishop Rock and Round Island (Scilly) now (1887) being prepared by Messrs. Chance for the Trinity House, the apparatus will be of the hyper-radial type, and it will have a vertical angle of 80°, with glass all of the usual refractive index. There will be for each lighthouse a biform structure 15 feet high, the Bishop having lenses for white double flashes arranged in a pentagon of five groups, each lens subtending 36° horizontally, with an eight-wick burner; and the Round Island having lenses for red single flashes, each lens subtending 60° horizontally, with a ten-wick burner. Petroleum will be used in both cases. The latter apparatus would seem to mark the maximum limit of dimension, with regard to optical agents and to illuminants, compatible with the present conditions of lanterns and towers. Hyper-radial apparatus is also being prepared in Paris for the Tory Island and Bull Rock lights in Ireland.

But the true maximum of power or intensity for lighthouses must ever be sought in the electric light. This application of the branch of physical science that has perhaps more than any other distinguished the Victorian epoch had its experimental beginnings, under the auspices of Faraday, at Dungeness and the South Foreland. The apparatus used at Dungeness was of 150 millimetres radius. In 1881 the apparatus for Macquarie was constructed of 920 millimetres radius. Six large electric lights have been established in Britain since 1862, all the work of Messrs. Chance, and all of their design except the Isle of May, which was planned by Mr. Thomas Stevenson. The Souter Point light, revolving, of second and third order elements, dates from 1871; the South Foreland, High and Low, fixed, of the third order, from 1872; the Lizard fixed lights, of the third order, from 1877; and the Isle of May, which gives a fourfold flash, and is of first and second order radii, from 1886. In addition, there have been designed by Dr. Hopkinson, and made at Birmingham, the Macquarie (Sydney), a first-order revolving, the most powerful light in the world, and the Tino (Spezia), a second-order triple group-flashing light. It is needless to give details of these apparatus, which are throughout distinguished by skilful optical combinations and the utmost precision of workmanship. They have all been, with the exception of the Isle of May, the subject of elaborate papers and exhaustive discussion before the Institution of Civil Engineers. An apparatus of the second order is being prepared at Birmingham for the new electric light of St. Catherine's (Isle of Wight). It is composed of refractors only, extended to 97° of vertical angle, and with certain special arrangements for divergence. The carbons will be of 50 millimetres diameter and of a novel and perfect form.

There has been during the past fifty years, but especially since 1861, with regard to lighthouse characteristics, a selective process in operation by which the fittest have survived. Not only has the optical apparatus been perfected in curvature, finish, and adjustment to nautical conditions, and the intensity of light increased threefold, but the weaker forms of distinction have been suppressed, and the better forms retained and multiplied. Fixed lights for the most part have been discontinued, and, in this country at least, lights composed of fixed and revolving portions. Long periods in revolving lights have been altered to short periods, the uncertain aid of colour largely abandoned, the varieties of the group-flashing system invoked, and the quick contrasts of light and dark resorted to in occulting or intermittent apparatus, although the very ingenious but too complicated plan of Babbage, with its rhythmical longs and shorts, has not prevailed. The enhanced speed of steam-vessels, the multiplication of all kinds of vessels, the improvement of shore-lights, and the spread of commercial enterprise, by which new ports are opened and new coasts explored, have naturally effected these changes. And, *pari passu*, striking improvements in the mechanism of revolving carriages and of clockwork both with weights and springs, in occulting-cylinders and gun-metal framing of apparatus, have resulted from the combined efforts of our best lighthouse engineers.

The early rivalry between the catoptric and the dioptric systems has wholly ceased, the latter having, by the weight of its general and well-tried superiority, displaced the old system in all directions save in one or two revolving sea-lights of exceptional merit, like Beachy Head or St. Agnes, and save in all light-vessels where the excellent 21-inch reflectors, with the two-wick Douglass burners, often send out beams of 20,000 candles over the shoal-beset waters.

There were in the United Kingdom, in 1886, 202 sea-lights, of which 147 were dioptric and 55 catoptric, and, in addition, about 450 small lights of all kinds, making, with the 74 light-vessels, a total of about 730. Surely this is a noble growth of lighthouse illumination, even in the long period under review. It compares not unfavourably with the United States, the first country to adopt the lenticular system on a bold and comprehensive scale, or even with the country of Fresnel himself and of his brother Léonor, where the elucidations and experiments of Allard and of Reynaud, and the practical work of Lepaute, Sautter, Barbier and Fenestre, have done much to promote science and benefit humanity.

J. KENWARD.

(*To be continued.*)

THE OBSERVATORIES AT OXFORD AND CAMBRIDGE.

THE following is the Annual Report of the Rev. Prof. Pritchard, the Savilian Professor of Astronomy at Oxford, to the Board of Visitors of the University Observatory; read June 8, 1887:—

I. *Lectures.*—The statutable lectures have been given, and the Observatory and its instruments have been freely accessible to the students during every day of Term time. For next Term I offer a course of elementary lectures expressed as far as possible in untechnical language. I desire to add also two public lectures on the development of astronomy during the last century.